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Research Report

Using landscape analysis to evaluate ecological impacts of battlefield restoration

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Introduction

Manassas National Battlefield Park (Virginia) was established to preserve the scene of two significant Civil War battles: the First Battle of Manassas, fought on 21 July 1861, and the Second Battle of Manassas, fought 28–30 August 1862. The park also serves as important wildlife habitat in the region. For Manassas and the other 10 parks of the National Capital Region Network, intense land use is a pervasive influence and tends to result in systems dominated by external stressors. The significance of these parks as natural resource refuges likely will increase as urbanization in and around Washington, D.C., leads to continued land conversion of adjacent habitats. Development is rapidly usurping natural areas in northern Virginia, and Manassas National Battlefield Park retains a regionally significant source of intact forest habitat (fig. 1).

Figure 2. Cannon fire along the flank of the attack was instrumental in turning back the Union advance at Manassas. Battle conditions at the time allowed clear line of sight for these cannons, which now face into a regenerating forest. To re-create these historic conditions, the National Park Service is considering a 124-acre (50 ha) cut of forest to the north of this position.

During the Civil War, Manassas National Battlefield Park was a patchwork of open fields and woodlots scattered across gently rolling hills. Much of the landscape has retained its battlefield character, but secondary forests have replaced open fields in some geographically significant areas. For instance, several skirmishes occurred before the Second Battle of Manassas on 326 acres (132 ha) of farmland rented by John Brawner at the time. This area is now situated along the far northwest corner of the park and has not been maintained since the battles. Current vegetation consists of a mix of mature basic oak-hickory forest interspersed with Virginia pine–eastern red cedar successional forest (Fleming and Weber 2003). These nonhistorical woodlands directly impact interpretation of the battles because forest vegetation now blocks the lines of sight that dictated troop movements and cannon fire (fig. 2, above). Open fields were a historically significant factor in shaping the outcome of much of the fighting.

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The need to maintain a historic battlefield setting within a piedmont-forest ecosystem creates two potentially opposing management strategies. The National Park Service must consider the effects of its management actions on internal park dynamics and regional-scale ecological processes. Park staff must continually balance natural resource protection (e.g., protecting large tracts of native forest) with cultural landscape preservation (e.g., preventing regeneration to preserve battlefield scenery). In order to restore historic battlefield conditions, the National Park Service plans to clear approximately 124 acres (50 ha) of timber bordering the Brawner Farm (see fig. 6). Harvesting at Manassas provides a case study of how analysis of potential changes in land cover and use (landscape dynamics) can be used to evaluate competing cultural and natural resource factors as a precursor to management action. Monitoring of landscape dynamics can be an extremely valuable source of information for natural resource managers working in mixed land use settings (Gross et al. 2006) and is currently the single most common “vital sign” monitored by the Inventory and Monitoring Program across the country (257 parks in 24 networks).

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Connectivity

As a consequence of urbanization, suitable habitat for plants and animals rarely occurs in large, contiguous units within the region. Instead, habitats are fragmented into individual parcels that lie within a matrix of less suitable land. In addition to their individual attributes (e.g., area, amount of edge, shape, and composition), these discrete, homogenous blocks of habitats, referred to as patches, have important properties associated with their collective spatial configuration. For plant and animal populations to thrive, individuals must be able to intersperse among patches. Connectivity is the measure of the spatial continuity of a network of patches or the ability of organisms to move from patch to patch across the landscape (Calabrese and Fagan 2004). Typically, habitat patches that are in closer proximity to one another will foster more dispersal; however, dispersal may occur between patches that are separated by greater distances via connectivity corridors (Beier and Noss 1998). Unfortunately, questions of optimal corridor width and configuration remain unresolved and are most likely influenced strongly by local environmental conditions (Petranka and Smith 2005).

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Figure 3. One consideration in assessing the removal of forest resources is the potential isolation of ephemeral ponds found in forests west of the proposed cut. These temporary pools provide valuable habitat to the park's amphibian populations.

We were interested in whether the proposed forest cut would result in isolation of ephemeral ponds used by the park's breeding amphibian populations, which are a group of species of concern for park management. Results of a 2000 field survey documented nine vernal (ephemeral) pools within the park (fig. 3, above) based on the presence of obligate amphibian species: spotted salamander (*Ambystoma maculatum*), marbled salamander (*Ambystoma opacum*), and wood frog (*Rana sylvatica*) (Loomis and Heffernan 2003). Isolation of ponds could affect the breeding success and survival of these animals. From the perspective of amphibian spatial dynamics, these ponds may be viewed as patches; however, growing evidence suggests that this interpretation misrepresents the importance of the terrestrial environment. The forest habitat surrounding the ponds influences feeding, overwintering, and nesting behavior (Semlitsch and Bodie 2003), as well as dispersal and movement of amphibians among ponds (Marsh and Trenham 2001). Therefore, we conducted a landscape analysis focusing on the pre- and postharvest distribution of forest habitat to evaluate potential changes in connectivity for amphibians resulting from the proposed Brawner Farm cut.

We would like to emphasize that this analysis is for amphibians and does not provide information about the potential benefit or harm of the cut to any other species. Amphibians were chosen specifically because of their demonstrated sensitivity to disturbance and widespread use as indicator species (e.g., Petranka and Smith 2005; Semlitsch et al. 2007). Nevertheless, because we selected forest patches as our focal unit of study, the results are similarly applicable to other forest-dwelling species with limited dispersal potential across non-forest land cover. For example, Corry and Nassauer (2004) report dispersal capabilities in nonforest of 886–1.411 feet (270–430 m) for small mammals, such as the least shrew (*Cryptotis parva*) and white-footed mouse (*Peromyscus* *leucopis*), within the range of distances analyzed. We expect that conditions will improve for a variety of other species (e.g., white-tailed deer, quail, and other avian species) following the cut.

Methods

We used graph theory, a well-developed framework for evaluating network connectivity, in our analysis. Methods associated with graph theory are used for evaluating spatial properties of communication and transportation networks (Harary 1969; Hayes 2000a and b) and more recently for assessing the consequences of habitat modification on landscapes (Bunn et al. 2000; Urban and Keitt 2001; Ferrari et al. 2007). Our analysis considers the landscape as a network of forest patches (fig. 4, below). In some cases the patches contain vernal pools and act as amphibian breeding habitat; in other cases the patches act only as preferred pathways for amphibians. The dispersal capabilities of the focal organism determine whether two patches are close enough to be considered connected. A landscape that is completely connected is one in which every patch can be reached from any other patch, either directly or via several intermediate connections.

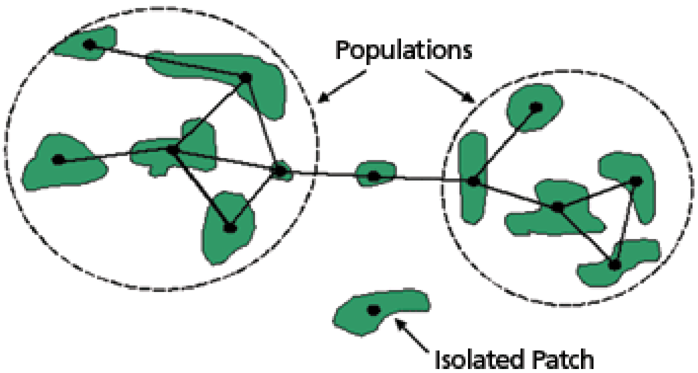

Figure 4. Investigators now use graph theory to assess the consequences of habitat modification on landscapes. Each green habitat patch of this hypothetical landscape is represented by a node (black dot). Lines between nodes represent potential dispersal movement, or connectivity, between pairs of patches. Two potentially separate populations are shown connected by a “stepping-stone” patch. An “isolated patch” that has been separated from its neighbors is also shown.

Our analysis integrated remotely sensed satellite imagery with digitized polygons of fencerows depicted on a Natural Heritage land cover map of the park (Fleming and Weber 2003). We used a 2006 SPOT satellite image to create a forest map for the park and adjacent land (total size was equal to six times the area of the park). To gain a broader understanding of landscape dynamics, we chose not to limit the analysis to park boundaries. Using GIS, we merged the fencerow data with the SPOT data and identified contiguous forest patches. In the study area we identified 3,800 forest patches, 629 of which were at least 2.5 acres (1 ha) in size. These 629 patches represent 10,378 acres (4,200 ha) or approximately 40% of the total area in this fragmented landscape. Continued monitoring will track changes in the amount of forest cover in and around the park. Nearly all remaining land was nonforest, composed of shrub and grassland.

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We created a series of graph representations of the park using the forest patch map. For the graph models we defined the maximum distance (D*max*) that an amphibian would be able to travel through nonforest to disperse from one patch to another. Because amphibians are vulnerable to desiccation, they are usually restricted to forest habitat, may be unable to cross large clearings, and are generally considered poor long-distance dispersers (Duellman and Trueb 1986). In a review of 64 salamander dispersal studies, 94% of the maximum reported dispersal distances were less than 0.6 mile (1 km) and 64% were less than 1,312 feet (400 m) (Smith and Green 2005). Experimentally derived dispersal distances across open fields are reported to be even lower (i.e., on the order of tens of meters) (Marsh et al. 2004). We therefore assumed an unlimited movement potential within forest patches, and examined the connectivity of the landscape for organisms capable of dispersing 33 feet (10 m) (Marsh et al. 2004) to 1,312 feet (400 m) (Smith and Green 2005) across nonforest habitat.

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By modeling this range of potential dispersal capabilities, we identified a critical dispersal threshold (D *crit* = 100 m) (fig. 5). This indicates the minimum distance an organism must be capable of traveling through nonforest in order to move among all available habitat in the park. We used Dcrit to construct two graphs representing potential amphibian connectivity under pre-treatment and post-treatment conditions. For each of these landscapes, we evaluated the total amount of connected forest and the connectivity status of known ephemeral ponds in the park.

Results

For amphibians and other animals (e.g., forest mice and shrews) capable of crossing 328 feet (100 m) of nonforested area, more than 95% of the forest in the network is considered to be connected for both pre- and post-treatment scenarios (fig. 5). For animals with more limited dispersal abilities (e.g., 32.8 feet [10 m] of nonforest), the network is considerably less connected under current conditions, but is also minimally reduced by the proposed cut (change of less than 2% between the two scenarios). This apparent insensitivity to the harvesting treatment is partly due to a large patch of intact forest located in the center of the landscape. This patch alone contains 64% of the total forest area and provides a corridor that facilitates interpatch movement. Given the current level of fragmentation, the management action is unlikely to have a significant impact on the ability of amphibians to move between forest patches at the landscape scale.

At the local level, the ephemeral pools to the west of the proposed cut are in danger of becoming isolated (fig. 6). One option would be to reduce harvesting in the western portion of the cut unit, but this would considerably reduce the effectiveness of the management goal to restore the battlefield. Alternatively, the existing fencerow trees along the western border of the cut could be augmented to allow establishment of a new connectivity corridor. Also, regrowth of forest habitat immediately surrounding the potentially more isolated vernal pools may offset the loss of habitat resulting from the forest cut.

Cahoun and deMaynadier (2004) recommends establishing two types of vernal pool management zones in forest habitats. “Vernal pool protection zones,” which are approximately 3.5 hectares (8.6 ac), serve to shade and protect the immediate surrounding habitat. “Amphibian life zones,” approximately 32 hectares (79 ac) in area, protect upland habitats needed by amphibians for foraging and during dry periods. In anticipation of the cut, the National Park Service established a protection zone/regeneration buffer around the potentially impacted vernal pool habitat in the Brawner Farm area, which increased surrounding habitat by 250% from 11–38 acres (4.5–15.5 ha) (fig. 6). While this action has the benefit of meeting both cultural and natural resource demands, park staff has adopted it with caution, as the harvesting and regrowth of forest occur on very different time scales.

Conclusions

Preserving ecological function in cultural settings presents a challenge to natural resource management. Our analysis provides a tool for anticipating the potential ecological consequences of changes in land cover associated with restoring battlefield scenery. Based on the results of this project, we expect that landscape connectivity will remain high following the proposed timber harvesting in Manassas National Battlefield Park, but at least one important region of amphibian habitat may become more isolated. The analysis allows us to be proactive rather than reactive in identifying and implementing management options to mitigate the impacts of habitat loss.

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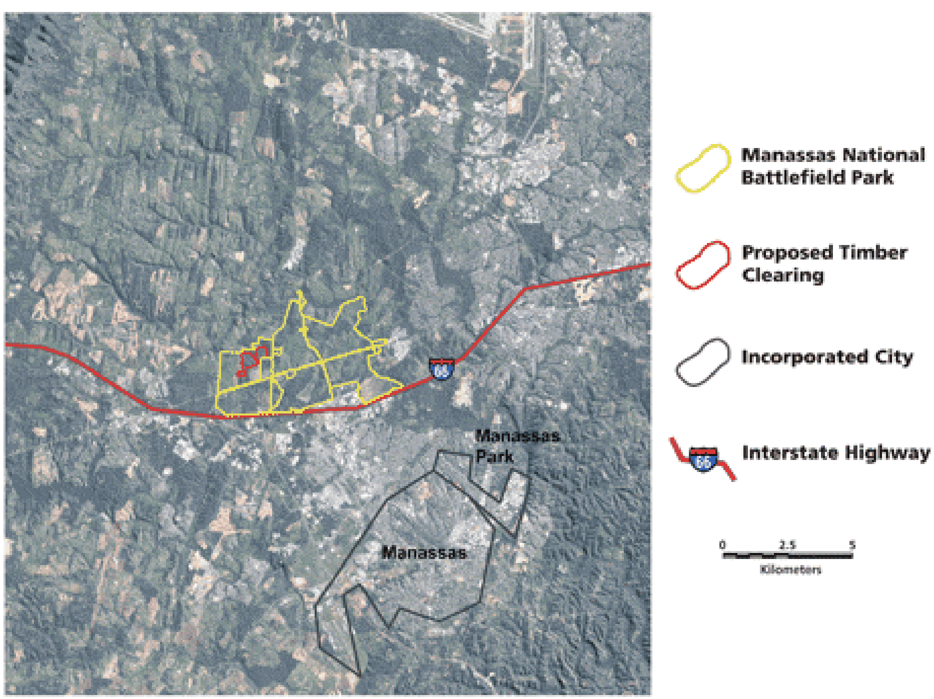

SATELLITE IMAGE: USGS EROS DATA CENTER

Figure 1. This Landsat ETM+ true-color composite image from 18 June 2002 shows the location of Manassas National Battlefield Park in the context of its urban and agricultural surroundings. This is one of several satellite images acquired as part of the Natural Resource Challenge (National Park Service 1999) and used by National Capital Region Network staff in making management decisions.

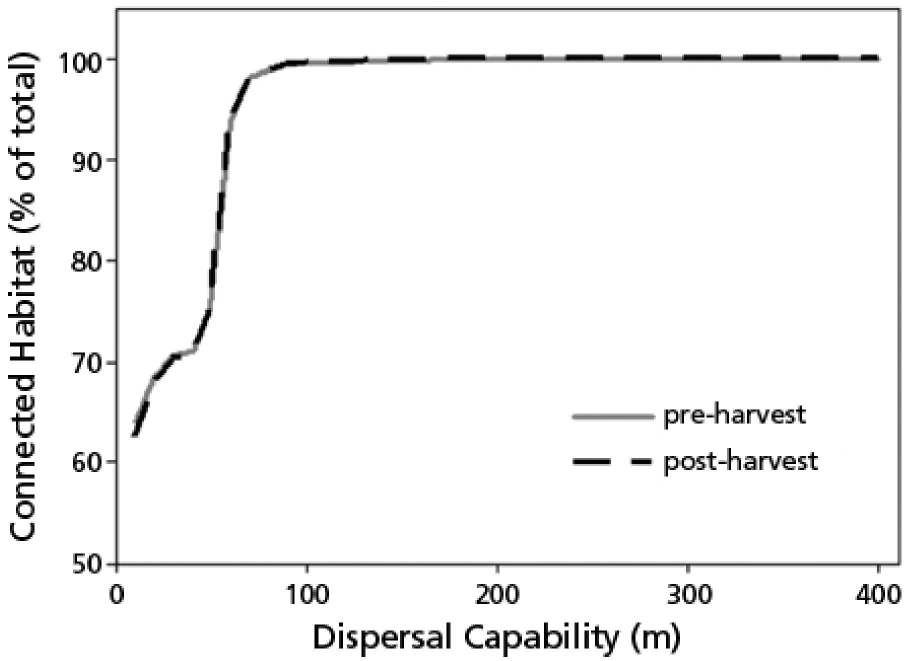

Figure 5. Comparison of connected habitat pre- and postharvest revelas the relatively small predicted effect of the cut. Connected habitat represents the percentage of forest that can be reached by an organism capable of dispersing a given distance across nonforest habitat. A threshold of connectivity occurs at 328 feet (100 m) such that amphibians capable of moving 328 feet (100 m) from one forest patch to another can move among greater than 95% of the habitat, but an organism capable of moving only 164 feet (50 m) can reach only 75% of the forest in the region. However, even for these poorer dispersers, network differences are relatively minor pre- and postharvest.

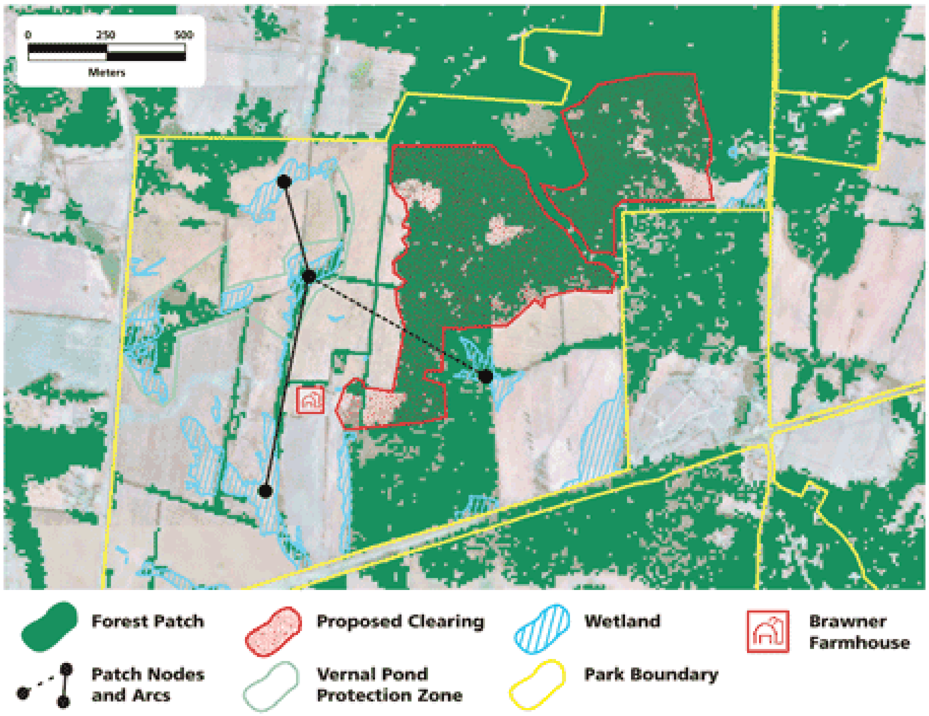

Figure 6. USGS digital ortho quarter quads (DOQQ) show network connections for significant wetland resources overlaid for the Brawner Farm and vicinity. Critical vernal ponds contained within the vernal pond protection zone could become isolated from the rest of the park after the proposed cut is completed. The dashed black line represents the pre-treatment connection from the proposed vernal pond protection zone to one of a number of large wetlands in the middle of the park. The vernal pond protection zone represents restoration actions the National Park Service has taken in anticipation of the cut.

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